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Claims

[c1] 1. A cooling system for providing cryogenic cooling fluid to an apparatus, the system comprising:

a re-circulation device;

a passive cold storage device having a porous matrix of material which directly contacts the cryogenic cooling fluid as the cryogenic cooling fluid passes through the passive cold storage device;

a first portion of a fluid communication feed line fluidly connecting the re-circulation device to the passive cold storage device;

a second portion of the fluid communication feed line fluidly connecting the passive cold storage device to the apparatus for communicating cryogenic cooling fluid to the apparatus; and

a fluid communication return line fluidly connecting the apparatus to the re-circulation device.

[c2] 2. A cooling system as in claim 1 wherein the passive cold storage device comprises a regenerative heat ex-changer.

[c3] 3. A cooling system as in claim 1 wherein the porous matrix of material of the passive cold storage device

comprises a porous matrix of metal wire mesh.

[c4] 4. A cooling system as in claim 1 wherein the porous matrix of material of the passive cold storage device comprises a porous matrix of metal spheres.

[c5] 5. A cooling system as in claim 1 wherein the porous matrix of material of the passive cold storage device comprises a porous matrix of ceramic spheres.

[c6] 6. A cooling system as in claim 1 wherein the first portion of fluid communication feed line includes at least one heat exchanger.

[c7] 7. A cooling system for providing a cooling fluid to an apparatus, the system comprising:
a cryogenic refrigerator for cooling the fluid to a first temperature when operating at a first refrigeration capacity and cooling the fluid to a second temperature when operating at a second refrigeration capacity, the first temperature being lower than the second temperature and the first refrigeration capacity being higher than the second refrigeration capacity;
a passive cold storage device having a porous matrix of material which directly contacts the cryogenic cooling fluid as the cryogenic cooling fluid passes through the passive cold storage device;

a first portion of a fluid communication feed line for communicating the fluid cooled by the cryogenic refrigerator to the passive cold storage device, the fluid communicated to the passive cold storage device cooling the passive cold storage device when the fluid has been cooled to the first temperature by the cryogenic refrigerator operating at the first refrigeration capacity, and the passive cold storage device cooling the fluid when the fluid provided to the passive cold storage device has been cooled to the second temperature by the cryogenic refrigerator operating at the second refrigeration capacity; and

a second portion of the fluid communication feed line fluidly connecting the passive cold storage device to the apparatus for communicating the fluid to the apparatus.

[c8] 8. A cooling system as in claim 7 wherein the passive cold storage device comprises a regenerative heat exchanger.

[c9] 9. A cooling system as in claim 7 wherein the porous matrix of the cold storage device comprises a porous matrix of metal wire mesh.

[c10] 10. A cooling system as in claim 7 wherein the porous matrix of the cold storage device comprises a porous matrix of metal spheres.

[c11] 11. A cooling system as in claim 7 wherein the porous matrix of material of the passive cold storage device comprises a porous matrix of ceramic spheres.

[c12] 12. A cooling system as in claim 7 wherein the passive cold storage device cools the fluid when the fluid provided to the cold storage device has been cooled to the second temperature and while the refrigeration capacity of the cryogenic refrigerator is being changed to the first refrigeration capacity.

[c13] 13. A method of providing a cooling fluid to an apparatus, the method comprising:
cooling the fluid utilizing a cryogenic refrigerator to a first temperature when the cryogenic refrigerator is operating at a first refrigeration capacity and to a second temperature when the cryogenic refrigerator is operating at a second refrigeration capacity, the first temperature being lower than the second temperature and the first refrigeration capacity being higher than the second refrigeration capacity;
communicating, as part of a fluid circuit, the fluid cooled by the cryogenic refrigerator to a passive cold storage device having a porous matrix of material directly contacting the fluid as the fluid passes through the passive cold storage device, the fluid cooling the passive cold

storage device when the fluid has been cooled to the first temperature by the cryogenic refrigerator operating at the first refrigeration capacity and the passive cold storage device cooling the fluid when the fluid has been cooled to the second temperature by the cryogenic refrigerator operating at the second refrigeration capacity; and

communicating, as part of the fluid circuit, the fluid from the passive cold storage device to the apparatus.

[c14] 14. A method as in claim 13 wherein the passive cold storage device comprises a regenerative heat exchanger.

[c15] 15. A method as in claim 13 wherein the porous matrix of the passive cold storage device comprises a porous matrix of metal wire mesh.

[c16] 16. A method as in claim 13 wherein the porous matrix of the passive cold storage device comprises a porous matrix of metal spheres.

[c17] 17. A method as in claim 13 wherein the porous matrix of the cold storage device comprises a porous matrix of ceramic spheres.

[c18] 18. A method as in claim 13 wherein the passive cold storage device cools the fluid when the fluid has been cooled to the second temperature and while the refriger-

ation capacity of the cryogenic refrigerator is being changed to first refrigeration capacity.

[c19] 19. A cooling system for providing cryogenic cooling fluid to an apparatus, the system comprising:
a re-circulation device;
a fluid communication feed line connecting the re-circulation device to the apparatus for communicating the fluid to the apparatus, the fluid communication feed line including:
a first passive cold storage device; and
a second passive cold storage device serially connected downstream from the first passive cold storage device; and
a fluid communication return line connecting the apparatus to the re-circulation device for communicating the fluid from the apparatus to the re-circulation device.

[c20] 20. A cooling system as in claim 19 wherein at least one of the first and second passive cold storage devices comprises a porous matrix of material which directly contacts the cryogenic cooling fluid as the cryogenic cooling fluid passes therethrough.

[c21] 21. A cooling system as in claim 20 wherein the porous matrix of material comprises a porous matrix of metal wire mesh.

[c22] 22. A cooling system as in claim 20 wherein the porous matrix of material comprises a porous matrix of metal spheres.

[c23] 23. A cooling system as in claim 20 wherein the porous matrix of material comprises a porous matrix of ceramic spheres.

[c24] 24. A cooling system as in claim 19 further comprising a first cryogenic refrigerator thermally coupled to the first passive cold storage device and a second cryogenic refrigerator thermally coupled to the second passive cold storage device.

[c25] 25. A cooling system as in claim 24 wherein the first cryogenic refrigerator cools the first passive cold storage device to a first temperature and the second cryogenic refrigerator cools the second passive cold storage device to a second temperature, the first and second temperatures being different.

[c26] 26. A cooling system as in claim 25 wherein the first temperature is higher than the second temperature.

[c27] 27. A method of providing a cooling fluid to an apparatus, the method comprising:
communicating the fluid to the apparatus through a fluid

communication feed line, the fluid communication feed line including a first passive cold storage device and a second passive cold storage device serially connected downstream from the first passive cold storage device; and

communicating the fluid from the apparatus to a re- circulating device through a fluid communication return line.

[c28] 28. A method as in claim 27 wherein at least one of the first and second passive cold storage devices comprises a regenerative heat exchanger.

[c29] 29. A method as in claim 27 wherein at least one of the first and second passive cold storage devices comprises a porous matrix of material which directly contacts the cryogenic cooling fluid as the cryogenic cooling fluid passes therethrough.

[c30] 30. A method as in claim 29 wherein the porous matrix of material comprises a porous matrix of metal wire mesh.

[c31] 31. A method as in claim 29 wherein the porous matrix of material comprises a porous matrix of metal spheres.

[c32] 32. A method as in claim 29 wherein the porous matrix of material comprises a porous matrix of ceramic

spheres..

[c33] 33. A method as in claim 27 further comprising thermally coupling a first cryogenic refrigerator to the first passive cold storage device and thermally coupling a second cryogenic refrigerator to the second passive cold storage device.

[c34] 34. A method as in claim 33 wherein the first cryogenic refrigerator cools the first passive cold storage device to a first temperature and the second cryogenic refrigerator cools the second passive cold storage device to a second temperature, the first and second temperatures being different.

[c35] 35. A method as in claim 34 wherein the first temperature is higher than the second temperature.

[c36] 36. A method as in claim 35 wherein at least a third passive cold storage device is connected downstream from the second passive cold storage device, the third passive cold storage device being cooled by a third cryogenic refrigerator to a third temperature, the second temperature being higher than the third temperature.

[c37] 37. A cooling system as in claim 26 further comprising at least a third passive cold storage device, the third passive cold storage device being cooled by a third cryo-

genic refrigerator to a third temperature, the second temperature being higher than the third temperature.